Learning Objectives

Students will develop skills with use of a digital oscilloscope, a function generator, and RC circuit to prepare and collect data for time varying signals. Completing this lab will help ensure the student can:

1. operate basic functions of a laboratory oscilloscope to perform voltage and frequency measurements on a time varying waveform from a function generator,

2. collect and analyze data to characterize the frequency response of an RC filter circuit

3. determine appropriate statements of uncertainty for oscilloscope measurements

4. *Optional: demonstrate use of multimeter to obtain more comparison values for voltage amplitudes and frequencies measured with oscilloscope.*

Background

See the Signal Filtering.pdf document provided for Challenge 5. You may also want to ensure you know how to make plots in Excel that have a semi-log scale axis.

- Signal Filtering

Activity 1 – Frequency response of a high-pass RC filter circuit

Construct the filter circuit shown in Figure 1.

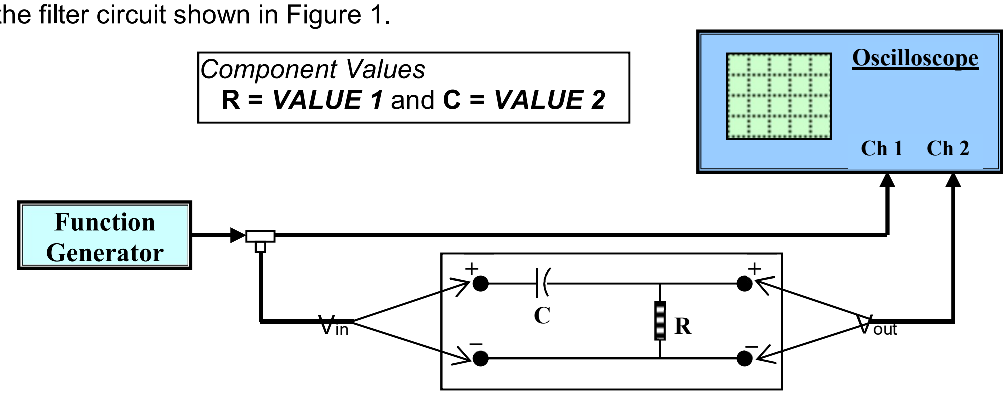

Figure 1. RC Filtered Signal Setup

Using a tee-connector, send the function generator output to Ch. 1 of the oscilloscope, this will be the input voltage and will be the non-filtered signal, V_{in}. Take the output voltage from across the resistor as shown in Figure 1 into Ch. 2 of the oscilloscope, this will be the filtered signal, V_{out}.

Use the function generator to produce a V_{in} sinusoidal waveform of ***VALUE 3*** magnitude with an initial frequency of **100,000 Hz**. From this point onward, **DO NOT change** the function generator magnitude, only adjust the frequency of the function generator signal, now referred to as the input signal for the filter. Note what the input and output look like on the oscilloscope, what are the amplitudes of each channel? Do the signals look to be in phase?

Note: *Make sure your RC circuit is functioning correctly by* ***skipping ahead to the 50 Hz frequency****. At this lower frequency, you should visually observe a significant reduction in amplitude of the filtered signal, V_{out} on channel 2. There should also be a noticeable shift in time between the two signals. If you do not observe a significant reduction in amplitude and see a phase shift, then the circuit needs to be checked, as it is not functioning correctly.*

From the oscilloscope display, see Figure 2 for an example display, measure the magnitude ($V_{pk\text{-}pk}$) for input and output and the time shift (Δt) of the filtered signal relative to the non-filtered signal. You can setup **cursor bands** to easily find the time shift. Report your process in your write-up.

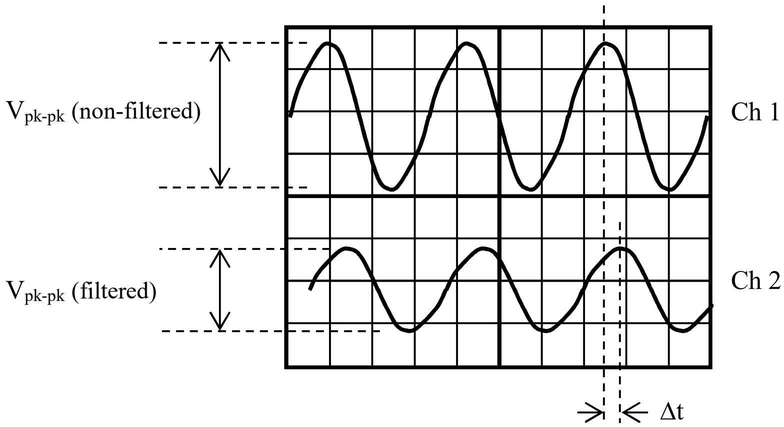

Figure 2. Sample O-scope Display of RC Filter Input and Output

Repeat the procedure to collect data of the magnitude of the output signal voltage, V_{out}, for a range of input frequencies between 10 Hz to 10,000 Hz. Prepare a table in Excel, using the headings shown below to organize the data.

The left column is the independent variable, f, the frequency of the input voltage. The second and third columns are the direct measurements taken from the oscilloscope display. The fourth column can either be directly measured as a filed in the Measure menu for the o-scope, or calculated from f, since f = 1/T. The fifth and sixth column are to be calculated from measured values and as such are considered to be indirect measurements of the system.

Frequency of Input signal f **(Hz)**	**Magnitude of Output Signal,** V_{out} $(V_{pk\text{-}pk})$	**Time Shift** Δt **(sec)**	**Period** T **(sec)**	**Gain** G (V_{out} / V_{in})	**Phase Shift** ***(deg)*** ϕ $(\Delta t / T) \times 360^o$

Collect data for the following input frequencies, as a minimal set of data for input frequencies below

100000, 50000, 30000, 10000, 5000, 3000, 1000, 500, 300, 100, 50, 30, and 10 Hz.

Note: you will need to change the time sampling base of the oscilloscope for these different values of frequencies to ensure you can view typically six to seven cycles on the display screen for your measurements.

Plot the Gain vs. Frequency on semi-log axes (x-axis log and y-axis linear)

Plot the Phase Shift vs Frequency, you decide what axes are best, justify your choice.

Analyze, Observe and Discuss: Examining your table of data and also your plots, make observations on the behavior of your circuit. Things to consider might include the effect of the RC circuit on the voltage input. During your analysis, consider how you have verified the classification of this RC circuit as a low-pass, high-pass, or band pass filter. Conduct a verification and validation by comparing your experimental data to the theoretical expected behavior of this RC circuit.

Activity 2

Design and implement a low pass filter with a cutoff frequency of 1kHz (approximately). Prove it works using a sinusoidal input of 1 V_{pk}.

Activity 3

Design and implement a high pass filter with a cutoff frequency of 1kHz (approximately). Prove it works using a sinusoidal input of 1 V_{pk}.

Suggested process, modify as needed:

- select R and C from the relationship f_{cutoff}.
- build the circuit on the breadboard
- apply a signal V_{in} = (1) V sin(2π f t), and measure V_{out} while increasing the frequency from 1Hz to 100kHz
- plot Gain with respect to input frequency.

Analyze, Observe, Discuss the results for Activity 2 and Activity 3.